AD NUMBER
AD091715
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Controlling Organization: British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.
AUTHORITY
DSTL, DSIR 23/24534, 5 Aug 2008; DSTL, DSIR 23/24534, 5 Aug 2008

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TECH. NOTE STRUCTURES 181

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TECH. NOTE STRUCTURES 181

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ROYAL AIRCRAFT ESTABLISHMENT

FARNBOROUGH, HANTS

TECHNICAL NOTE No: STRUCTURES 181

A RECORD OF INFORMATION ON BRITISH WING FLUTTER EXPERIMENTS

by

D.R.GAUKROGER

DECEMBER, 1955

MINISTRY OF SUPPLY

ENCLOSURE 14 TO Astia 27-56 CONFIDENTIAL

AIR ATTACHE, LONDON

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56AA 55587

U.D.C. No. 533.69.042.001.5(42) : 533.6.013.422

Technical Note No. Structures 181

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A Record of Information on British Wing Flutter Experiments

by

D. R. Gaukroger

R.A.E. Ref: Structures D/7513/DRG

SUMMARY

This note contains the results of a survey of British experimental work on wing flutter. Seventeen published reports are listed of work undertaken at the National Physical Laboratory and at the Royal Aircraft Establishment, and it is believed that these reports contain details of nearly all the quantitative investigations of wing flutter that have been made.

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1 Introduction

In January 1954 the National Advisory Committee for Aeronautics in the United States published a research memorandum giving a summary, in tabular form, of much of the experimental wing flutter work undertaken in America[1] since the war. It was suggested that a similar publication dealing with British work would be useful. In the preparation of this note a survey has been made of all the reports and papers on wing flutter that could be found. Presentation of the results in tabular form, however, has not been possible because much of the earlier testing was either qualitative or very limited in scope. It was decided, therefore, to confine the detailed survey to reports of investigations that could be summarised in tabular form to provide a useful comparison with other results. All data published before 1941 has been omitted. It is suggested that the record might be kept up to date by the periodical issue of supplements.

The present note is confined to wing flutter, and it is felt that a similar survey could be made of publications dealing with experimental work on control surface and tab flutter. This might also include a supplementary section covering flutter tests that do not fall into the categories of main and control surface flutter. Such a note together with the present note would then provide a comprehensive index of quantitative flutter experiments.

2 Survey of experimental work on wing flutter

The initial survey of available material showed that most of the experimental work on wing flutter could be divided into three groups, depending on the period in which the work was undertaken. The first period covers the years up to 1939, and is mainly work of a qualitative nature. Most of the tests made in this period were on small models of simple construction, and in many cases the tests were undertaken in conjunction with theoretical work. The second period broadly covers the war years from 1939 up to about 1947, and during this period the work was largely done at the National Physical Laboratory. The third period, from 1947 to the present day, covers mainly investigations made at the Royal Aircraft Establishment. The seventeen reports listed in this note come from the second and third periods.

A certain amount of flutter work has been undertaken by various organisations such as universities, colleges and aircraft firms. As far as can be ascertained the universities and colleges have made only limited inroads in the experimental flutter field, and no details of their work are included in this note. Amongst the aircraft firms, experimental flutter investigations have so far been limited to work directly connected with specific aircraft projects and again these have been omitted from this note.

Detailed comparison of the British and American records[1] shows that a large proportion of American work has been devoted to flutter at Mach numbers between 0.4 and 0.8, whereas practically no British results for this Mach number range exists. This is because wind tunnels covering this Mach number range are not available for flutter work in Britain. For Mach numbers above 0.8, American tests considerably outnumber British, and much of the American work at sonic and transonic speeds has been done in wind tunnels, whereas all the British tests at these speeds were made with ground launched rockets or freely falling models. In the low speed range (Mach numbers less than 0.2) British work has been more extensive than American, and the effect of body freedoms on flutter has received more attention in Britain than in the United States.

3 Tabulation of information

The reports analysed are listed in Table I, which gives the title, author, reference number and date of publication of each; an additional reference number, shown in the first column of Table I, is used in subsequent tables of this note.

Table II consists of a precis of each report. The precis is divided into four sections:- Summary, Parameter variations, Model details and Test conditions. The Summary briefly describes the experiments and the variable parameters involved. Under 'Parameter variations' the actual ranges of values investigated are listed. The 'Model details' section lists the following:-

(a) Angle of sweepback of a specified axis.

(b) Aspect ratio ($= \frac{(2S)^2}{A}$ where S is the root to tip span, and A is the full span wing area).

(c) Taper ratio $\left(= \frac{\text{tip chord}}{\text{root chord}} \right)$.

(d) Semi-span.

(e) Mean chord.

(f) Aerofoil section.

(g) Thickness/chord ratio.

(h) Density ($= \frac{W}{S\, c_m^2}$ where W is the weight of one wing, S is the semispan and c_m is the mean chord).

(i) Flexural axis (the measured flexural axis where stiffness tests have been made; otherwise, the design axis).

(j) Inertia axis.

(k) Type of construction.

The flexural and inertia axis positions are expressed as fractions of the wing chord.

The final section of Table II, (Test conditions), gives the site of the tests, the range of Mach number and the range of frequency parameter ν where $\nu = \frac{\omega c_m}{V}$, ω being the frequency of the flutter in radians per second, c_m the mean chord of the wing, and V the flutter speed.

Table III gives a list of the parameters investigated, and the corresponding report in which any particular variation may be found.

Table IV shows the investigations made at each angle of sweepback. This is arranged in order of increasing sweepback and gives brief details of the tests together with the appropriate reference. Table V is similar to Table IV but in this case the tests are listed under increasing values of aspect ratio.

The tables are followed by two diagrams (Figs.1 and 2) showing the range of Mach number (Fig.1) and range of frequency parameter (Fig.2) covered in all the tests. The number of tests made in each investigation is also indicated in the diagrams.

REFERENCES

No.	Author	Title, etc.
1	H. J. Cunningham and Harvey L. Brown	A compilation of experimental flutter information. N.A.C.A. RM.L53K02a T.I.B. 4061 January, 1954.

Attached: Tables I - V
Figs. 1 - 2
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TABLE I

Wing Flutter - List of Reports

No.	Author	Title	Reference
1	W.P. Jones N.C. Lambourne	Derivative measurements and flutter tests on a model tapered wing.	R & M 1945 A.R.C. 5258 0.229 August, 1941.
2	W.P. Jones N.C. Lambourne	Some tests on the effect of wing tip shape on flutter.	A.R.C. 5394 0.240 October, 1941
3	N.C. Lambourne D. Weston	An experimental investigation of the effect of localised masses on the flutter and resonances of a model wing. (Part I - flutter tests.)	A.R.C. 7604 0.405 April, 1944
4	N.C. Lambourne	An experimental investigation on the flutter characteristics of a model flying wing.	A.R.C. 10,509 0.655 April, 1947
5	W.G. Molyneux	The flutter of swept and unswept wings with fixed root conditions.	R.A.E. Report Structures 58 A.R.C. 13,306 0.881 January, 1950
6	W.G. Molyneux E.W. Chapple	Flutter experiments with freely falling models at high subsonic speeds	R.A.E. Report Structures 67 A.R.C. 13,722 0.923 May, 1950
7	D.R. Gaukroger E.W. Chapple A. Milln	Wind tunnel flutter tests on a model delta wing under fixed and free root conditions.	R.A.E. Report Structures 89 A.R.C. 13,721 0.922 September, 1950
8	W.G. Molyneux F. Ruddlesden P.J. Cutt	Flutter tests on unswept wings using ground launched rockets.	R.A.E. Report Structures 118 A.R.C. 14,606 0.975 November, 1951
9	D.R. Gaukroger	Wind tunnel tests on symmetric flutter of sweptback wings, including the tailplane effect.	R.A.E. Report Structures 123 A.R.C. 15,054 0.1001 April, 1952
10	W.G. Molyneux E.W. Chapple	The aerodynamic effects of aspect ratio on flutter of unswept wings.	R.A.E. Report Structures 135 A.R.C. 15,609 0.1040 November, 1952
11	D.R. Gaukroger	Wind tunnel tests on anti-symmetric flutter of sweptback wings with rolling body freedom.	R.A.E. Report Structures 143 A.R.C. 16080 0.1065 March, 1953
12	W.G. Molyneux F. Ruddlesden	Some flutter tests on sweptback wings using ground launched rockets.	R.A.E. Report Structures 155 A.R.C. 16551 0.1108 October, 1953

TABLE I (CONTD)

No.	Author	Title	Reference
13	D.R. Gaukroger	Wind tunnel tests on the effect of a localised mass on the flutter of a sweptback wing with fixed root.	R.A.E. Report Structures 159 A.R.C. 16811 0.1125 December, 1953
14	P.F. Jordan	A wind-tunnel test concerning Glauert flutter.	R.A.E. Tech. Note Structures 116 May, 1953
15	W.G. Molyneux F. Ruddlesden	Flutter tests on some delta wings using ground launched rockets.	R.A.E. Report Structures 173 February, 1955
16	D.R. Gaukroger D. Nixon	Wind tunnel tests on antisymmetric flutter of a delta wing with rolling body freedom.	R.A.E. Report Structures 174 February, 1955
17	W.G. Molyneux H. Hall	The aerodynamic effects of aspect ratio and sweepback on wing flutter.	R.A.E. Report Structures 175 February, 1955.

TABLE II

Summaries of Reports

A.R.C. paper 5258 O.229

Report 1

"Derivative measurements and flutter tests on a model tapered wing" by W. P. Jones and N. C. Lambourne.

Summary

A model wing, fixed at the root, having a 'built-in' torsional stiffness, and an externally applied flexural stiffness was tested for a range of values of the stiffness ratio. The values were obtained by varying the flexural stiffness.

Parameter variations

Stiffness ratio $\frac{\ell_\phi}{d^3} \div \frac{m_\theta}{dc_m{}^2}$ from zero to 17.5.

Model details

Sweepback (flexural axis):	0^o	Density (lb/ft^3):	-
Aspect ratio:	5.84	Flexural axis:	0.3
Taper ratio:	0.52	Inertia axis:	0.4
Semi-span (in.)	54	Construction:	Wood, with silk covering
Mean chord (in.)	18.5		
Aerofoil section	N.A.C.A.23012		
Thickness/chord ratio:	0.12		

Test conditions

Site of test:	-
Range of Mach. No.:	0 to 0.1
Range of frequency parameter:	0.7 to 1.3
Number of tests:	42

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Report 2 A.R.C. paper 5394 0.240

"Some tests on the effect of wing tip shape on flutter" by W. P. Jones and N. C. Lambourne.

Summary

A model wing, fixed at the root, having a 'built-in' torsional stiffness and an externally applied flexural stiffness was tested with two different shapes of the tip having the same area and similar inertia properties. The flexural stiffness was varied with each shape of wing tip.

Parameter variations

Shape of wing tip: (i) A 'square-cut' tip with the same taper ratio as the original wing, increasing the span by 8.8%.

(ii) A 'rounded' tip increasing the span by 11.1%.

Flexural stiffness ℓ_ϕ : 163.7 to 953.2 lb ft/radian.

Model details (without tip shapes)

Sweepback (flexural axis):	0°	Density (lb/ft^3):	-
Aspect ratio:	5.84	Flexural axis:	0.3
Taper ratio:	0.52	Inertia axis:	0.4
Semi-span (in.):	54	Construction:	Wood, with silk covering
Mean chord (in.):	18.5		
Aerofoil section:	N.A.C.A.23012		
Thickness/chord ratio:	0.12		

Test conditions

Site of test:	-
Range of Mach No.:	0 to 0.04
Range of frequency parameter:	Not available
Number of tests:	8

Report 3 A.R.C. paper 7604 0.405

"An experimental investigation of the effect of localised masses on the flutter and resonances of a model wing" by N. C. Lambourne and D. Weston.

Summary

A model wing, tapered but unswept and fixed at the root was subject to localised mass loadings at 0.1, 0.3, 0.5 span sections and also at the tip. The localised masses were attached to the wing both singly and in combinations of up to four masses. The mass values were from zero to ten times the wing mass, and in some cases infinite values of the mass were represented by fixing rigidly the point of application.

Parameter variations

Localised mass value:	zero to infinity
Localised mass spanwise position:	0.1, 0.3, 0.5 span and tip
Localised mass chordwise position:	from 0.4 of the wing local chord aft of the flexural axis to 0.6 forward
Number of localised masses:	1, 2, 3 or 4.

Model details:

Sweepback:	0°	Density (lb/ft^3):	0.50
Aspect ratio:	5.84	Flexural axis:	0.30
Taper ratio:	0.52	Inertia axis:	0.40
Semi-span (in.)	72	Construction:	spruce with silk covering
Mean chord (in.)	24.7		
Aerofoil section:	Symmetric cubic oval		
Thickness/chord ratio:	0.15		

Test conditions

Site of tests:	N.P.L. 9 ft × 7 ft closed wind tunnel
Range of Mach. No.:	0 to 0.13
Range of frequency parameter:	0.45 to 1.30
Number of tests:	403

Report 4 A.R.C. paper 10,509 0.655

"An experimental investigation on the flutter characteristics of a model flying wing" by N. C. Lambourne.

Summary

Two full span model 'flying wings', one of rectangular planform and one of cranked and tapered planform were tested under conditions of symmetric and antisymmetric body freedom. The effects of the three body freedoms, pitch about a fixed axis, normal translation, and roll about the centre line were separately investigated, and body inertia parameters were varied in some cases.

Parameter variations

Pitching axes of body: 0.2 and 0.39 of model root chord.
Pitching moment of inertia of body) = (wing mass × (mean chord)^2): 0.25 to 1.0.

Model details

	Rectangular planform	Cranked planform
Sweepback (leading edge)	0°	0° and 45°
Aspect ratio	4.52	5.33
Taper ratio	1.0	0.52
Semi-span (in.)	28	28
Mean chord (in.)	12.4	12.4 and 9.45
Aerofoil section	-	-
Thickness/chord ratio	-	-
Density (lb/ft^3)	-	-
Flexural axis	0.23 to 0.33	-
Inertia axis	-	-

Construction: Two wooden spars with wooden ribs and silk covering.

Test conditions

Site of test:	-
Range of Mach No.:	0 to 0.1
Range of frequency parameter:	0.05 to 0.5
Number of tests:	106

Report 5 R.A.E. Report, Structures 58

"The flutter of swept and unswept wings with fixed root conditions" by W. G. Molyneux.

Summary

Four model wings of different taper ratios were tested. For each model, the inertia axis and the angle of sweepback were varied.

Parameter variations:

Taper ratio:	1.0, 0.75, 0.5, 0.25
Angle of sweepback (spar):	0°, 20°, 30°, 35°, 40°, 50°
Inertia axis:	0.40, 0.45, 0.50

Model details of 0° sweepback

Aspect ratio	8.00	8.00	8.00	8.00
Taper ratio	1.00	0.75	0.50	0.25
Semi-span (in.)	48	48	48	48
Mean chord (in.)	12	12	12	12
Aerofoil section	-	-	-	-
Thickness/chord ratio	-	-	-	-
Density (lb/ft^3)	1.25	1.25	1.25	1.25
Flexural axis	0.35	0.35	0.35	0.35
Inertia axis	0.4, 0.45 or 0.5	0.4, 0.45, or 0.5	0.4, 0.45 or 0.5	0.4, 0.45 or 0.5
Construction	Single wooden spar, wooden ribs and silk covering.			

Test conditions

Site of tests:	R.A.E. 5 ft open jet wind tunnel
Range of Mach No.:	0.06 to 0.17
Range of frequency parameter:	0.3 to 0.9
No. of tests:	60

Report 6 R.A.E. Report Structures 67

"Flutter experiments with freely falling models at high subsonic speeds" by W. G. Molyneux and E. W. Chapple.

Summary

Four flexible model wings carried by a freely falling heavy body were tested. Only two of the models failed in flutter. Of these, one was fixed at the root, and the other was free in pitch and normal translation.

Parameter variations

Body freedoms in pitch and normal translation.

Model details

Sweepback (leading edge):	40°	Density (lb/ft^3):	0.54
Aspect ratio	1.88	Flexural axis:	-
Taper ratio	1.0	Inertia axis:	0.47
Semi-span (in.)	24.5	Construction:	Stressed skin
Mean chord (in.)	26.11		
Aerofoil section	R.A.E.101		
Thickness/chord ratio	0.10		

Test conditions

Site of test:	Scilly Isles range
Range of Mach. No.:	0.80 and 1.04
Range of frequency parameter:	0.4 and 0.5
No. of tests:	2

Report 7 R.A.E. Report Structures 89

"Wind tunnel flutter tests on a model delta wing under fixed and free root conditions" by D. R. Gaukroger, E. W. Chapple and A. Milln.

Summary

A model delta wing with variable inertia axis position was tested under conditions of root fixed, and root free in pitch and normal translation. The fuselage mass, pitching moment of inertia and centre of gravity were varied in the body free condition.

Parameter variations

Wing inertia axis:	0.40, 0.45, 0.50
Overall C.G. position:	45, 47.5 and 50% of wing root chord
Fuselage pitching moment of inertia:	from -0.05 to +0.2 of the wing pitching moment of inertia
Fuselage mass:	from 0.15 to 0.7 of the wing mass

Model details

Sweepback (leading edge):	45°	Density (lb/ft^3):	0.92
Aspect ratio:	3.53	Flexural axis:	0.15
Taper ratio:	0.0625	Inertia axis:	0.4, 0.45, 0.5
Semi-span (in.)	45	Construction:	Wood with silk covering
Mean chord (in.)	25.5		
Aerofoil section	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site:	R.A.E. 5 ft open jet wind tunnel
Range of Mach No.:	0.09 - 0.14
Range of frequency parameter:	0.4 - 0.8
No. of tests:	126

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Report 8 R.A.E. Report Structures 118

"Flutter tests on unswept wings using ground launched rockets" by W. G. Molyneux, F. Ruddlesden and P. J. Cutt.

Summary

31 ground launched rocket models were tested, all unswept and untapered, and designed to the same planform. The tests were made to determine the effect of rocket acceleration and compressibility on wing flutter.

Parameter variation:

Rocket acceleration:	14g to 43g at critical flutter speed
Mach No.:	0.47 to 0.98

Model details

Sweepback:	0^{o}	Density (lb/ft^3):	0.55 to 2.31
Aspect ratio:	4.0	Flexural axis:	0.22 to 0.36
Taper ratio:	1.0	Inertia axis:	0.34 to 0.47
Semi-span (in.):	24		
Mean chord (in.):	12		
Aerofoil section:	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site of test:	Larkhill artillery range
Range of Mach. No.:	0.47 to 0.98
Range of frequency parameter:	0.16 to 0.59
No. of tests:	31

Report 9 R.A.E. Report Structures 123

"Wind tunnel tests on symmetric flutter of sweptback wings, including the tailplane effect" by D. R. Gaukroger.

Summary

A model wing was tested under conditions of fixed root and freedom in pitch and normal translation. The angle of sweepback was varied and with the root free the fuselage pitching moment of inertia, overall centre of gravity, and tailplane volume coefficient were varied.

Parameter variations

Sweepback (spar):	0°, 5°, 9°, 13°, 23°, 33°, 43°
Fuselage pitching moment of inertia ÷ wing pitching moment of inertia: from −2.0 to +12.0	
Overall centre of gravity:	three positions, on, forward and aft of the aerodynamic centre with no tailplane, and on the neutral point with tailplane
Tailplane volume coefficient:	0 to 0.3

Model details for 23° sweepback (design condition)

Aspect ratio:	4.92	Density (lb/ft):	1.31
Taper ratio:	0.29	Flexural axis:	0.30
Semi-span (in.):	36	Inertia axis:	0.43
Mean chord (in.):	13.5	Construction:	Wood with silk covering
Aerofoil section:	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site of test:	R.A.E. 5 ft open jet wind tunnel
Range of Mach. No.:	0.06 to 0.12
Range of frequency parameter:	0.25 to 0.75
Number of tests:	140

Report 10 R.A.E. Report Structures 135

"The aerodynamic effects of aspect ratio on flutter of unswept wings" by W. G. Molyneux, E. W. Chapple.

Summary

Eight rigid model wings untapered and unswept having freedoms about the root in pitch and roll were tested for all combinations of three pitching frequencies and two rolling frequencies.

Parameter variations

Aspect ratio:	2.0, 2.3, 2.6, 3.0, 3.3, 4.0, 5.0, 6.0
Pitching frequency:	11.0, 12.5, 14.2 cycles/second
Rolling frequency:	4.0, 5.5 cycles/second

Model details

Sweepback:	0^o	Density (lb/ft^3):	-
Taper ratio:	1	Flexural axis:	0.35
Semi-span (in.):	6-18	Inertia axis:	-
Mean chord (in.):	6	Construction:	solid wood, spruce and balsa
Aerofoil section:	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site of test:	R.A.E. 5 ft open jet wind tunnel
Range of Mach No.:	0.05 to 0.10
Range of frequency parameter:	0.18 to 0.35
Number of tests:	48

Report 11 R.A.E. Report Structures 143

"Wind tunnel tests on antisymmetric flutter of sweptback wings with rolling body freedom" by D. R. Gaukroger.

Summary

A model wing was tested under conditions of fixed root and freedom in roll. The angle of sweepback of the model, and the rolling moment of inertia of the fuselage were varied.

Parameter variations

Sweepback (spar): 13°, 23°, 33°, 43°, 53°
Fuselage rolling moment of inertia ÷ wing rolling moment of inertia: -0.2 to +0.5

Model details for 23° sweepback (design condition)

Aspect ratio:	4.92	Density (lb/ft^3):	1.31
Taper ratio:	0.29	Flexural axis:	0.30
Semi-span (in.):	36	Inertia axis:	0.43
Mean chord (in.):	13.5	Construction:	Wood, with silk covering
Aerofoil section:	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site of test:	R.A.E. 5 ft open jet wind tunnel
Range of Mach No.:	0.07 to 0.13
Range of frequency parameter:	0.42 to 0.62
No. of tests:	35

Report 12 R.A.E. Report Structures 155

"Some flutter tests on sweptback wings using ground launched rockets" by W. G. Molyneux, F. Ruddlesden.

Summary

37 ground launched rocket models were tested, 1 with 20° sweepback, 19 with 40°, and 9 with 60°. All were untapered models. The tests were made to determine the effect of sweepback on flutter in compressible flow.

Parameter variation

Sweepback: 20°, 40°, 60°

Model details

	20° sweepback	40° sweepback	60° sweepback
Aspect ratio:	3.3	2.7	1.75
Taper ratio:	1.0	1.0	1.0
Semi-span (in.):	18.36	18.36	18.36
Mean chord (in.):	12.72	15.72	24.00
Thickness/chord ratio:	0.094	0.077	0.050
Density (lb/ft^3):	1.3 to 2.0	0.9 to 1.6	0.8 to 1.0
Flexural axis:	0.20 to 0.37	0.03 to 0.28	-0.23 to 0.08
Inertia axis:	0.39 to 0.45	0.39 to 0.47	0.42 to 0.50
Aerofoil section:	R.A.E.101	R.A.E.101	R.A.E.101

Test conditions

Site of test:	Larkhill artillery range
Range of Mach No.:	0.47 to 1.16
Range of frequency parameter:	0.25 to 0.45
No. of tests:	37

Report 13 R.A.E. Report Structures 159

"Wind tunnel tests on the effect of a localised mass on the flutter of a sweptback wing with fixed root" by D. R. Gaukroger.

Summary

The investigation covers the effects of wing sweepback on the flutter of a model wing fixed at the root and carrying a localised mass. The spanwise and chordwise position of the mass have been varied, together with mass value and pitching radius of gyration. The effects of aerodynamic shape have also been investigated.

Parameter variations

Sweepback (span):	13°, 23°, 33°, 43°
Localised mass value:	0.13 to 1.17 of wing mass
Localised mass pitching radius of gyration:	0.10 to 0.45 of wing mean chord
Localised mass spanwise position:	0.25, 0.5, 0.75 span and at tip
Localised mass chordwise position:	from 0.5 of wing mean chord aft of spar to 0.4 forward
Aerodynamic shape:	two shapes of fuel tank at two spanwise positions

Model details at 23° sweepback (design condition)

Aspect ratio:	4.92	Density (lb/ft^3):	1.31
Taper ratio:	0.29	Flexural axis:	0.30
Semi-span (in.):	36	Inertia axis:	0.43
Mean chord (in.):	13.5	Construction:	Wood with silk covering
Aerofoil section:	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site of test:	R.A.E. 5 ft open jet wind tunnel
Range of Mach No.:	0.04 to 0.18
Range of frequency parameter:	0.12 to 0.82
Number of tests:	458

Report 14 R.A.E. Tech. Note Structures 116

"A Wind-Tunnel test concerning Glauert flutter", by P. F. Jordan.

Summary

An attempt was made to obtain single degree of freedom pitching flutter in a low speed open jet wind tunnel. Flutter did not occur owing to the tunnel fan cutting off the vortex trail shed by the model. The position of the pitching axis and the frequency parameter were varied.

Parameter variations

Position of pitching axis: varied over an unspecified range for preliminary qualitative tests, but fixed at d = $^1/_3$ for the quantitative tests, where d is the distance of the pitching axis forward of the leading edge divided by the wing chord.

Frequency parameter: 0.018 to 0.036.

Model details

Sweepback	0^o	Density (lb/ft^3):	-
Aspect ratio (effective)	13	Construction:	Solid mahogany
Taper ratio	1		
Semi-span (in.)	48		
Mean chord (in.)	12		
Aerofoil section	R.A.E.103		
Thickness/chord ratio:	0.12		

Test conditions

Site of test: R.A.E. 5 ft open jet wind tunnel
Range of Mach. No.: 0 to 0.2
Range of frequency parameter = 0.018 to 0.036
No. of tests: 6

Report 15 R.A.E. Report Structures 173

"Flutter tests on some delta wings using ground launched rockets" by W. G. Molyneux and F. Ruddlesden.

Summary

Nine ground launched rocket models of delta planform were tested with various leading edge sweepback angles. All were cropped deltas having the same span and taper ratio.

Parameter variation

Sweepback: 40°, 50° and 60°.

Model details

	40° sweepback	50° sweepback	60° sweepback
Aspect ratio	3.57	2.53	1.74
Taper ratio	0.143	0.143	0.143
Semi-span (in.)	24	24	24
Mean chord (in.)	13.44	18.96	27.60
Aerofoil section	R.A.E.101	R.A.E.101	R.A.E.101
Thickness/chord ratio	0.090	0.070	0.045
Density (lb/ft^3)	1.39 - 2.59	0.94 - 1.78	0.60 - 1.04
Flexural axis	0.10 - 0.42	0.03 - 0.33	0.01 - 0.27
Inertia axis	0.45 - 0.50	0.43 - 0.50	0.42 - 0.43

Test conditions

Site of test:	Larkhill artillery range
Range of Mach. No.:	0.75 - 1.8
Range of frequency parameter:	0.33 - 0.70
No. of tests:	9

Report 16 R.A.E. Report Structures 174

"Wind tunnel tests on antisymmetric flutter of a delta wing with rolling body freedom" by D. R. Gaukroger and D. Nixon.

Summary

A model delta wing was tested with a body freedom in roll. The fuselage rolling moment of inertia was varied over a wide range of values.

Parameter variations

Fuselage rolling moment of inertia ÷ wing rolling moment of inertia: -0.05 to +0.34.

Model details

Sweepback (leading edge):	45^{o}	Density (lb/ft^3):	0.92
Aspect ratio:	3.53	Flexural axis:	0.15
Taper ratio:	0.0625	Inertia axis:	0.50
Semi-span (in.):	45	Construction:	Wood with silk covering
Mean chord (in.):	25.5		
Aerofoil section:	R.A.E.101		
Thickness/chord ratio	0.10		

Test conditions

Site:	R.A.E. 5 ft open jet wind tunnel
Range of Mach. No.:	0.10 - 0.17
Range of frequency parameter:	0.30 - 0.80
No. of tests:	15

Report 17 R.A.E. Report Structures 175

"The aerodynamic effects of aspect ratio and sweepback on wing flutter" by W. G. Molyneux and H. Hall.

Summary

Six sets of rigid model wings both tapered and sweptback having freedoms about the root in pitch and roll were tested in a low speed wind tunnel.

Parameter variations

Aspect ratios:	1.72 to 6.0
Sweepback angles:	0° to 60°

Model details

Sweepback:	0° to 60°	Density (lb/ft^3):	-
Aspect ratios:	1.72 to 6.0	Flexural axis:	0.35
Taper ratios	1.0, 0.5 and 2.0	Inertia axis:	-
Semi-span (in.):	6 to 18	Construction:	solid wood, spruce and balsa
Mean chord (in.):	6		
Aerofoil section:	R.A.E.101		
Thickness/chord ratio:	0.10		

Test conditions

Site of test:	R.A.E. 5 ft open jet wind tunnel
Range of Mach. No.:	0.06 to 0.09
Range of frequency parameter:	0.14 to 0.27
No. of tests:	43

TABLE III

List of parameters investigated

Parameter		References
Sweepback	Wing geometry	5, 9, 11, 12, 15, 17
Aspect ratio	Wing geometry	10, 17
Taper ratio	Wing geometry	5
Tip shape	Wing geometry	2
Inertia axis	Inertia and stiffness characteristics	5, 7
Flexural stiffness	Inertia and stiffness characteristics	1, 2, 10
Torsional stiffness	Inertia and stiffness characteristics	10
Aircraft centre of gravity	Body free inertia characteristics	7, 9
Fuselage mass	Body free inertia characteristics	7
Fuselage pitching moment of inertia	Body free inertia characteristics	4, 7, 9
Fuselage rolling moment of inertia	Body free inertia characteristics	11, 16
Tailplane volume coefficient	Body free geometrical characteristics	9
Pitching axis of fuselage	Body free geometrical characteristics	4
Acceleration	Performance	8
Mach. No.	Performance	8, 12, 15
Localised mass value	Fixed root cases	3, 13
Localised mass position	Fixed root cases	3, 13
Single degree of freedom flutter		14

TABLE IV

Sweepback Table

Angle	Measured At	Report	Test Details
0°	Flexural axis	1	Variation of stiffness ratio.
0°	Flexural axis	2	Variation of flexural stiffness and wing tip shape.
0°	Flexural axis	3	Variation of localised mass parameters - fixed root.
0°	Leading edge	4	Variation of symmetric body freedom parameter.
0° and 45°	Leading edge	4	Cranked planform. Variation of symmetric body freedom parameters.
0°	Spar	5	Variation of wing inertia axis and taper ratio.
0°	Leading edge	8	Rocket tests to investigate Mach. No. and acceleration effects.
0°	Spar	9	Variation of symmetric body freedom parameters and tailplane volume coefficient.
0°	Leading edge	10	Variation of pitching and rolling frequency, and aspect ratio.
0°	Leading edge	14	Test of single degree of freedom flutter.
0°	Leading edge	17	Variation of aspect ratio.
5°	Spar	9	Variation of symmetric body freedom parameters and tailplane volume coefficient.
9°	Spar	9	Variation of symmetric body freedom parameters and tailplane volume coefficients.
10°	Leading edge	17	Variation of aspect ratio.
13°	Spar	9	Variation of symmetric body freedom parameter and tailplane volume coefficient.
13°	Spar	11	Variation of antisymmetric body freedom parameter.
13°	Spar	13	Variation of localised mass parameter - fixed root.
20°	Spar	5	Variation of wing inertia axis and taper ratio.

TABLE IV (CONTD)

Angle	Measured At	Report	Test Details
20°	Leading edge	12	Rocket tests to investigate Mach. No. effects.
20°	Leading edge	17	Variation of aspect ratio.
23°	Spar	9	Variation of symmetric body freedom parameters and tailplane volume coefficient.
23°	Spar	11	Variation of antisymmetric body freedom parameters.
23°	Spar	13	Variation of localised mass parameters - fixed root.
30°	Spar	5	Variation of wing inertia axis and taper ratio.
30°	Leading edge	17	Variation of aspect ratio.
33°	Spar	9	Variation of symmetric body freedom parameter and tailplane volume coefficient.
33°	Spar	11	Variation of antisymmetric body freedom parameters.
33°	Spar	13	Variation of localised mass parameters - fixed root.
35°	Spar	5	Variation of wing inertia axis and taper ratio.
40°	Spar	5	Variation of wing inertia axis and taper ratio.
40°	Leading edge	6	Variation of root fixing at high Mach. No. and symmetrical body freedom.
40°	Leading edge	15	Rocket tests to investigate Mach. No. effects.
40°	Leading edge	17	Variation of aspect ratio.
43°	Spar	9	Variation of symmetric body freedom parameters.
43°	Spar	11	Variation of antisymmetric body freedom parameters.
43°	Spar	13	Variation of localised mass parameters - fixed root.
45° and 0°	Leading edge	4	Cranked planform. Variation of symmetric body freedom parameters.
45°	Leading edge	7	Delta planform. Variation of wing inertia axis and symmetric body freedom parameters.
45°	Leading edge	16	Delta planform. Variation of fuselage rolling moment of inertia.

TABLE IV (CONTD)

Angle	Measured At	Report	Test Details
45°	Leading edge	17	Variation of aspect ratio.
50°	Spar	5	Variation of wing inertia axis and taper ratio.
50°	Leading edge	15	Delta planform. Rocket tests to investigate Mach. No. effects.
50°	Leading edge	17	Variation of aspect ratio.
53°	Spar	11	Variation of antisymmetric body freedom parameters.
60°	Leading edge	12	Rocket tests to investigate Mach. No. effects.
60°	Leading edge	15	Delta planform. Rocket tests to investigate Mach. No. effects.
60°	Leading edge	17	Variation of aspect ratio.

TABLE V

Aspect Ratio Table

Aspect Ratio	Report	Test Details
1.72	17	Variation of sweepback.
1.74	15	Delta planform. Rocket tests to investigate Mach. No. effects.
1.88	6	Variation of root fixing at high Mach. No.
2.00	10	Variation of pitching and rolling frequencies.
2.00	17	Variation of sweepback.
2.04	17	Variation of sweepback.
2.31	17	Variation of sweepback.
2.33	10	Variation of pitching and rolling frequencies.
2.33	17	Variation of sweepback.
2.53	15	Delta planform. Rocket tests to investigate Mach. No. effects.
2.62	17	Variation of sweepback.
2.66	10	Variation of pitching and rolling frequencies.
2.67	15	Delta planform. Rocket tests to investigate Mach. No. effects.
2.67	17	Variation of sweepback.
3.00	10	Variation of pitching and rolling frequencies.
3.00	17	Variation of sweepback.
3.33	10	Variation of pitching and rolling frequencies.
3.33	17	Variation of sweepback.
3.53	7	Delta planform. Variation of wing inertia axis and symmetric body freedom parameters.
3.53	16	Delta planform. Variation of fuselage rolling moment of inertia.
3.57	15	Delta planform. Rocket tests to investigate Mach. No. effects.
4.00	8	Rocket tests to investigate Mach. No. and acceleration effects.
4.00	10	Variation of pitching and rolling frequencies.

TABLE V (CONTD)

Aspect Ratio	Report	Test Details
4.00	17	Variation of sweepback.
4.52	4	Variation of symmetric body freedom parameters.
4.92	9	Variation of sweepback, symmetric body freedom parameter, and tailplane volume coefficient.
4.92	11	Variation of sweepback and antisymmetric body freedom parameters.
4.92	13	Variation of sweepback and localised mass parameters - fixed root.
5.00	10	Variation of pitching and rolling frequencies.
5.00	17	Variation of sweepback.
5.33	4	Variation of symmetric body freedom parameters.
5.84	1	Variation of stiffness ratio.
5.84	2	Variation of flexural stiffness ratio and wing tip shape.
5.84	3	Variation of localised mass parameters - fixed root.
6.00	10	Variation of pitching and rolling frequencies.
6.00	17	Variation of sweepback.
8.00	5	Variation and wing inertia axis, taper ratio and angle of sweepback.
13.00	14	Single degree of freedom pitching flutter test.

FIG. 1.

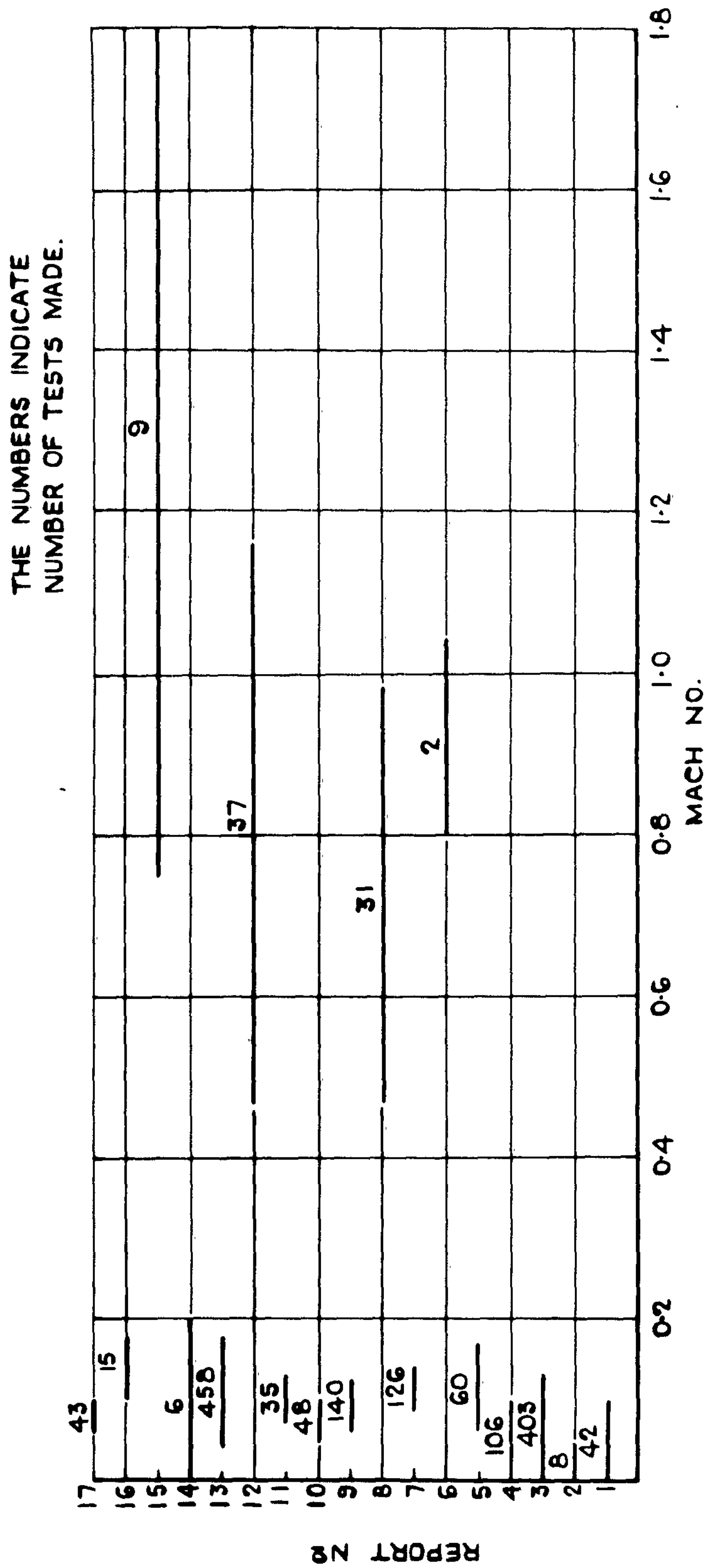

FIG. 1. RANGE OF MACH NUMBER COVERED BY THE TESTS.

FIG. 2.

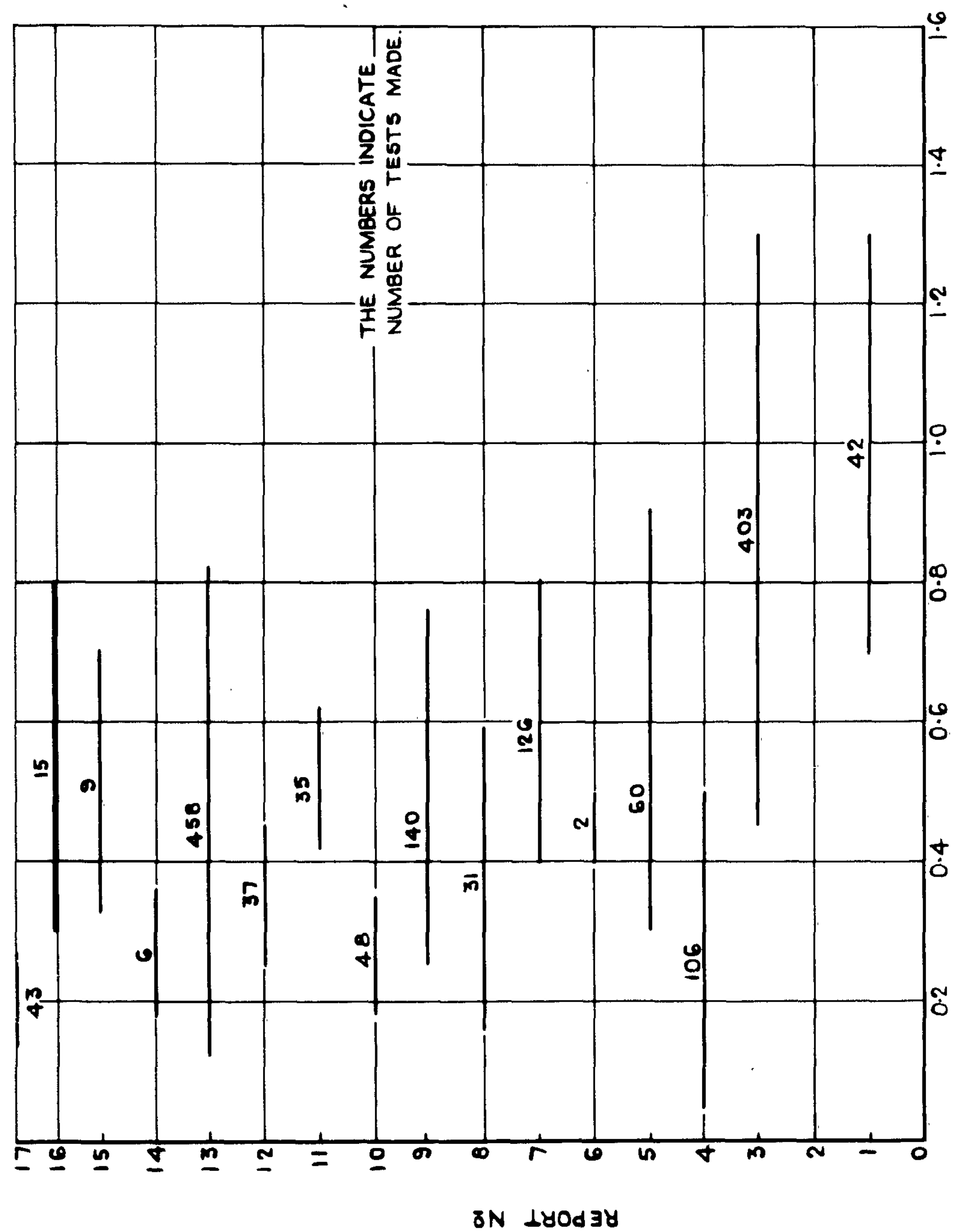

FIG.2. RANGE OF FREQUENCY PARAMETER COVERED BY THE TESTS.

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